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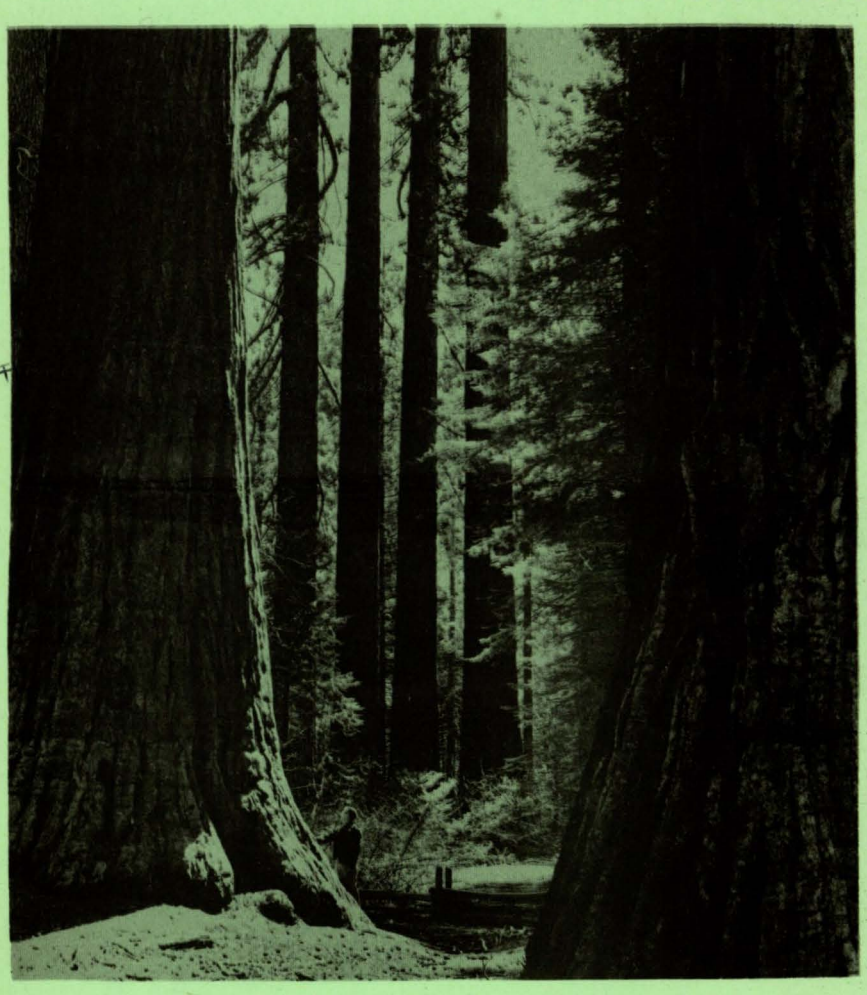
TECHNICAL PAPER NUMBER 20

# SILVICAL CHARACTERISTICS OF GIANT SEQUOIA

G. H. SCHUBERT



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## Preface

The Forest Service is engaged in assembling information on the silvical characteristics of important forest trees of the United States. Much material that is of value in silviculture and research is widely scattered and difficult to locate. This report presents, in preliminary form, the information that has been collected for one species of tree. Similar reports are being prepared for other species at the California Forest and Range Experiment Station and at other forest experiment stations. Readers are encouraged to notify the authors of omissions, errors, or new information affecting the silvical characteristics of the species.

# SILVICAL CHARACTERISTICS OF GIANT SEQUOIA

By Gilbert H. Schubert, Forester
Division of Forest Management Research

Technical Paper No. 20 November 1957

CALIFORNIA FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

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The Experiment Station is maintained at Berkeley, California in cooperation with the University of California.

Agriculture--Forest Service, Berkeley, California

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# SILVICULTURAL CHARACTERISTICS OF GIANT SEQUOIA

By Gilbert H. Schubert, Forester,
Division of Forest Management Research

Giant sequoia (Sequoia gigantea (Lindl.) Decne) is the world's largest tree in terms of volume (23). Within its natural range it occurs in more or less isolated groves on the western slopes of the Sierra Nevadas in central California. These groves, variously listed at 25 to 72 by different authorities (6, 8, 10, 11, 13, 14, 20, 23, 26, 28), lie in a narrow belt approximately 260 miles long (fig. 1). The northernmost grove, consisting of six trees, is along the Middle Fork of the American River in Placer County. The southernmost grove with 100 trees in it, is near Deer Creek in Tulare County.

## HABITAT CONDITIONS

### CLIMATIC

The climate in the areas where giant sequoia grows is cooler and drier than where the redwoods (Sequoia sempervirens (D. Don) Endl.) occur (26, 28). Annual precipitation, which varies with altitude and from year to year, ranges from 18 inches to more than 60 inches (23, 26, 28). The best stands grow in protected locations where the average annual precipitation is from 45 to 60 inches (23).

Most of the precipitation occurs in form of snow during the months of September through May. Summer storms are infrequent. Snow falls throughout the range of giant sequoia and accumulates in places up to 10 or more feet. During the winter of 1905-1906, snow in the Giant Forest (Sequoia National Park) was 29 feet deep; in protected spots, snow was still 12 feet deep by mid-summer (10).

The temperature occasionally drops to -12°F. and seldom exceeds 100°F. In the Giant Forest, one of the largest and best developed groves, the minimum temperature is -5°F. and the maximum is 94°F. The average growing season in this grove is 124 days--June 2 to October 4 (27).

### EDAPHIC

Giant sequoia grows on a wide variety of soils from shallow rocky, to deep sandy loams (28). Although it grows on shallow moderately dry soils, it does best on moist, deep, well-drained soils slightly to moderately acid in reaction. These soils are generally developed from granitic, dioritic, and andesitic rocks. The most common soil series are: Holland, Olympic, and Sierra.

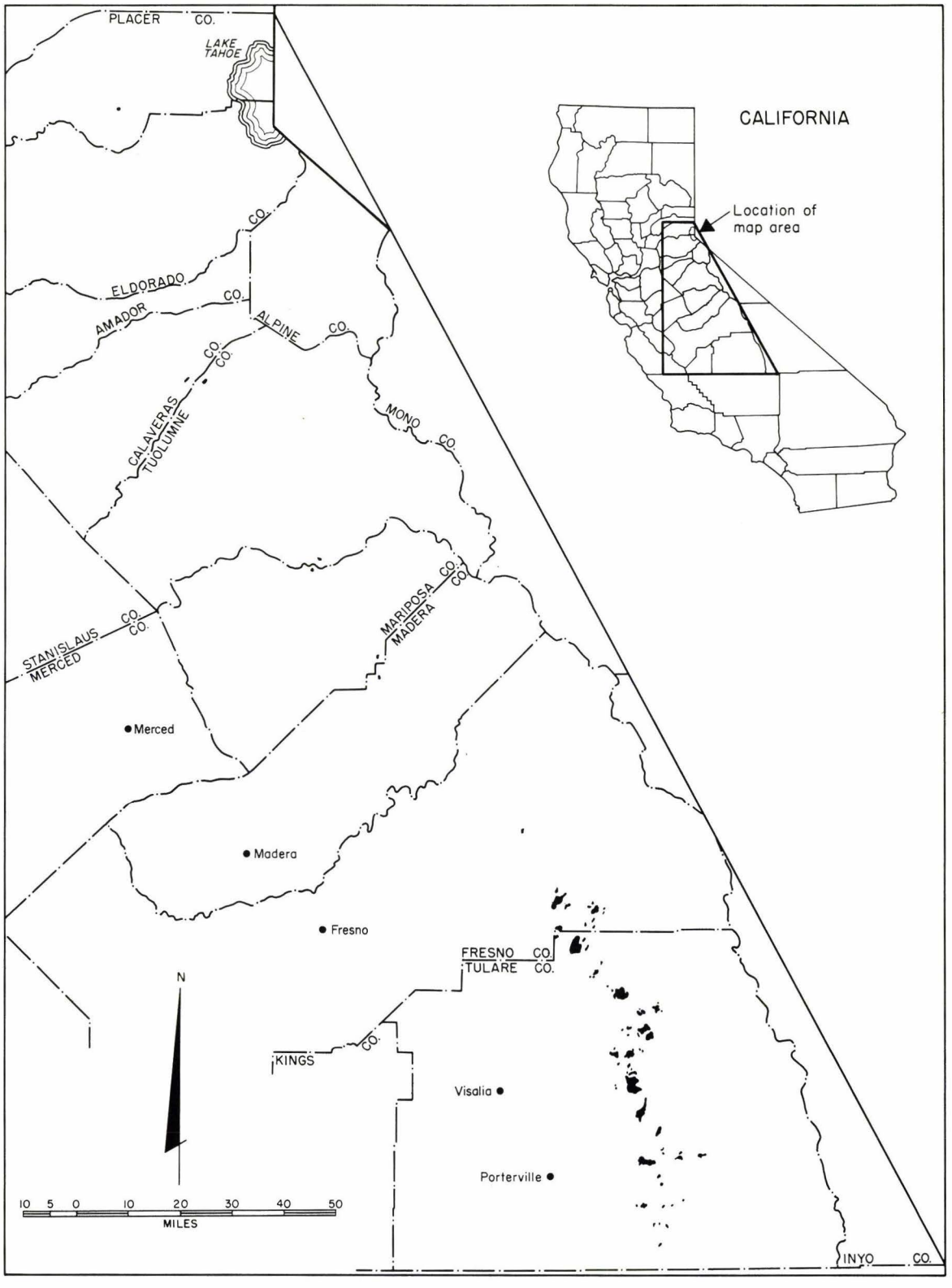


Figure 1.--The natural range of giant sequoia. (Adapted from California Department of Natural Resources (6).)

## PHYSIOGRAPHIC

Most of the groves are at elevations between 4,500 and 7,500 feet (6, 23). Some occur as low as 3,000 feet and a few grow at 8,900 feet. At the northern part of its range the trees occur at 4,500 to 5,500 feet; in the central part, at 5,400 to 7,000 feet; and at the southern end, at 6,000 to 8,000 feet.

Giant sequoias grow on slopes of all aspects. The groves are generally found in canyons where soil moisture is always adequate but also occur on or near the tops of high exposed ridges where underground water is available (6, 11, 28).

## BIOTIC

Giant sequoias occur in small groves within the ponderosa pine-sugar pine-fir type (25). They never make up pure stands except over small areas.

Trees commonly associated with giant sequoia are:

White fir (Abies concolor (Gord. & Glend.) Lindl.)
Sugar pine (Pinus lambertiana Dougl.)
Ponderosa pine (P. ponderosa Laws.)
Incense-cedar (Libocedrus decurrens Torr.)
California black oak (Quercus kelloggii Newb.)

Other trees found growing with giant sequoia are:

Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco)
California red fir (A. magnifica A. Murr.)
Jeffrey pine (P. jeffreyi Grev. & Balf.)
Pacific dogwood (Cornus nuttallii Audubon)
Bigleaf maple (Acer macrophylum Pursh)
Canyon live oak (Q. chrysolepis Liebm.)
White alder (Alnus rhombifolia Nutt.)
Bitter cherry (Prunus emarginata Dougl.)

Common brush species occurring with giant sequoia are:

Greenleaf manzanita (Arctostaphylos patula Green)
Mountain whitethorn (Caenothus cordulatus Kell.)
Deerbrush (C. integerrimus H. & A.)
Snowbrush (C. velutinus Dougl.)
Littleleaf ceanothus (C. parvifolius Trel.)
Bearmat (Chamaebatia foliolosa Benth.)
Bush chinkapin (Castanopsis sempervirens Dudley)
Scouler willow (Salix scouleriana Barr.)
Western azalea (Rhododendron occidentale Gray)

## LIFE HISTORY

### SEEDING HABITS

#### Flowering and Fruiting

Male and female flower buds are formed on the same tree during late summer, but are not discernible until the following spring when they begin to swell and open (4). The ovule-bearing strobili originate on the larger twigs near the tips of branches but rarely on the leaders. The pollen-bearing strobili are formed on the smaller twigs.

Pollination usually occurs between the middle of April and the first of May when the conelets are only 2 to 3 times as large in diameter as the twigs on which they are borne (4). By the end of the first growing season the conelets are about one-third mature size. They reach mature size of 2 to 3.5 inches in length at the end of the second growing season (5).

In one study the number of seeds per cone varied from 97 to 306, and averaged about 230 (10). The greatest number of seeds reported from a single cone was 329 (10).

#### Seed Production

Giant sequoias usually begin to produce large numbers of cones only after they have reached an age of 150 to 200 years (11). Cones have been observed on 18- to 24-year-old saplings, but they usually contain only infertile seeds (11, 23, 28). Heavy cone crops with viable seeds have been reported on some trees 50 to 75 years old (17).

Cones are generally produced each year and enormous quantities are borne on the largest trees (28). The immense size of the tree and the relatively small size of the cones make it impossible to count accurately all the cones on a tree.

Not all cones which first appear on the tree survive to maturity. One instance was reported when all 1-year-old cones were frozen in the early summer of 1906 (10). None of the 2-year-old cones on the same trees were affected. Some immature cones may have been destroyed by freezing during other years, but no other report on freezing injury was located.

Squirrels, particularly the Douglas squirrel (Tamiasciurus douglasii Backman) cut down and cache vast numbers of mature cones for their winter food supply (10). These cone caches provide a convenient seed source for seed collectors.

No seed or cone insects or diseases of economic importance have been reported for giant sequoia.

### Seed Dissemination

In contrast with the habit of most conifers, giant sequoia seeds are not usually released the first year after the cones mature (4, 10). Viable seeds may be retained in the cones for more than 14 years (10). One cone, on a branch broken off a large tree during a wind storm, was 19 years old (4). This cone still contained 137 seeds--more than half the average number of seeds normally found in cones at maturity.

The tissue in the peduncle of mature cones that remain closed on the tree produce annual rings (4). Cones with only 2 growth rings in the peduncle are immature, whereas those having 3 or more rings are mature. Annual rings continue to form in cones that have not shed all their seeds and therefore can be used to determine the age and maturity of the cones. Cones which open and release all of their seeds die, turn brown, and do not form annual rings thereafter.

Giant sequoia seeds are very light and may be carried for great distances by air currents. The number of seeds varies from 54,000 to 132,000 per pound; the average is 91,000 (19, 28). Exact distances that wind will carry these light seeds are not known; however, it is believed to be several hundred yards (11). In one instance seeds were carried by wind for 580 feet (10).

## VEGETATIVE REPRODUCTION

Giant sequoia does not produce sprouts from roots or stumps as is common in redwood, but tall broken stubs and crowns sprout vigorously (26) and form new tops if sufficient live foliage remains below the point of breakage.

## SEEDLING DEVELOPMENT

### Establishment

Giant sequoia seeds germinate best on exposed mineral soil and in loose ashes on a freshly burned area (23, 28, 29). Very few seedlings are found in the northern groves where the litter is deep and dry. In the central and southern groves reproduction is abundant only where the soil has been disturbed following logging, fire, erosion, windthrow, or road construction (fig. 2).

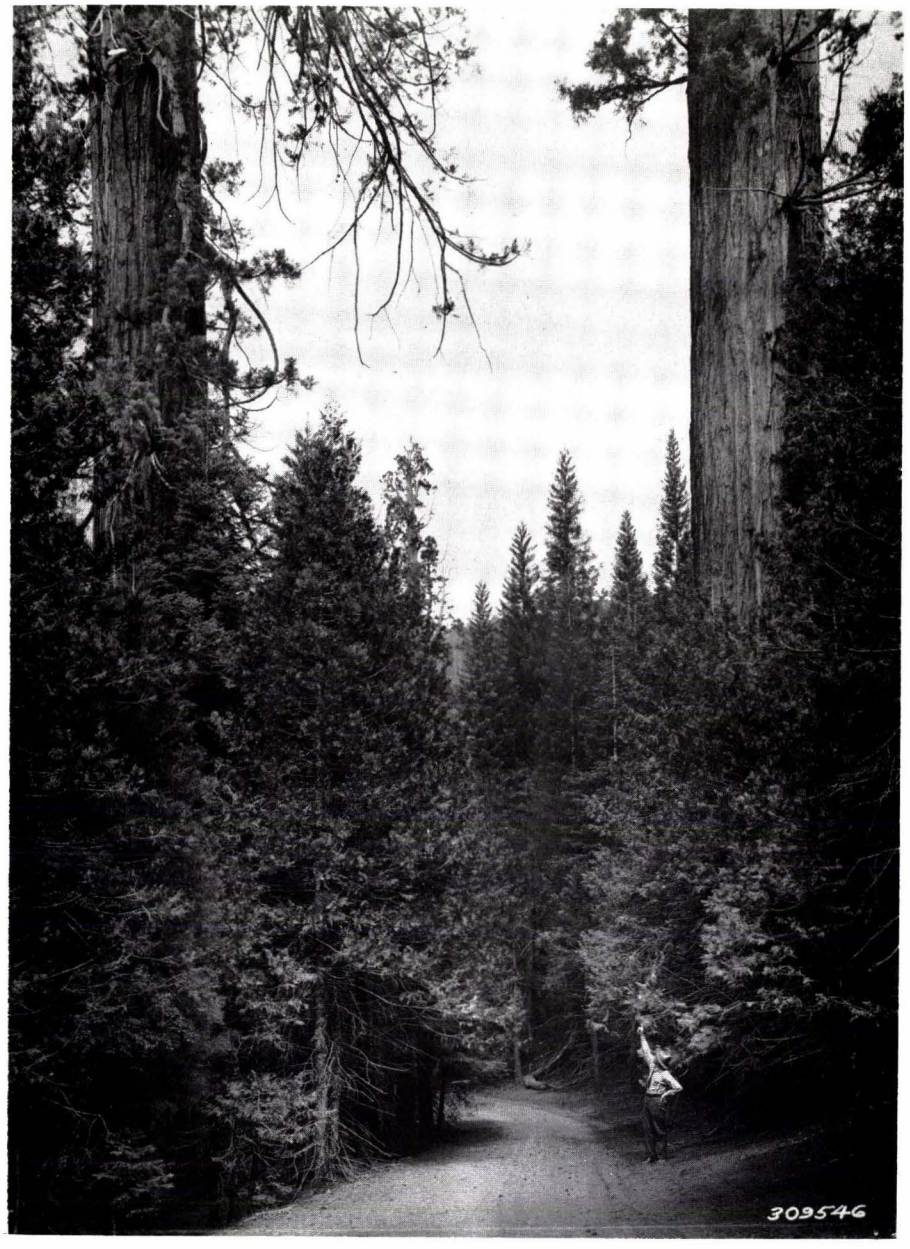


Figure 2.--Dense giant sequoia reproduction along road.

Field germination and survival, even on the better sites, are low. Although exact records have never been made, probably only one seed in a million germinates under natural conditions and only a small percentage of these survive (10). One of the main reasons for poor establishment has been an inadequate moisture supply, especially on areas covered with competing vegetation or dry litter.

Seeds stored in cones on the tree and in cold storage retain their viability for long periods (4, 10, 22). Two seed lots held in cold storage at 5°C. (41°F.) still had a viability of 41 to 43 percent after 16 and 17 years (22).

During the initial stages of seedling establishment some shade may be required. In a nursery study, none of the seedlings survived full exposure to sunlight, 16 percent survived under partial shade, and 68 percent survived in full shade (24). Since giant sequoia seedlings do survive in the open under natural conditions, other causes of mortality, such as excessive heat or drying, may have been the deciding factors in the nursery study.

Heavy losses of seedlings are frequently noted for giant sequoia. Sparrows (Zonotrichia spp.), the California purple finch (Carpodacus purpureus californicus), cutworms (Noctuidae spp.), ground squirrels (Citellus spp.), and chipmunks (Eutamias spp.) destroy many seedlings during the first few months after germination. Many seedlings also die in areas where the soil is too wet or too dry. Severe root competition for the limited soil-moisture supply is a factor in preventing the establishment of seedlings in old stands (17).

### Early Growth

Height growth of giant sequoia seedlings is slow during the first year but increases rapidly after the second or third year (23). One-year-old seedlings are from 1 to 3 inches tall. By the end of the second year they are 3 to 6 inches, and after 3 growing seasons 6 to 12 inches. Trees 35 years old average between 45 and 87 feet tall depending on site quality and competition with older trees (17). With an even start, giant sequoias are capable of outgrowing any of the associated species (17).

Exact root growth measurements have not been reported; but root elongation is probably rapid. During the first few years, the main root system consists of a taproot with few laterals (20). After 6 to 8 years lateral root growth is predominate, and elongation of the taproot practically stops. Later in the life of the giant sequoia, the lateral root system may spread over an area of 2 to 3 acres with none of the roots more than 6 to 8 feet deep (10, 20). This wide-spread root system provides excellent support for the trees throughout their life span.

## SEASONAL GROWTH

There are no published data on beginning dates or duration of seasonal radial or height growth of giant sequoia.

## SAPLING STAGE TO MATURITY

### Growth and Yield

Although giant sequoia is not the tallest species, and although occasional individuals of other species may surpass it in basal circumference, it is the most massive tree in the world (23). The highest volume of a single tree was estimated to be 600,120 board-feet; many trees have a gross volume of more than 500,000 board-feet (8).

The General Sherman tree in the Giant Forest has the greatest circumference of the measured trees. It has a basal circumference of 101.6 feet at 4.5 feet and a height of 272 feet (1). The tallest giant sequoia (California tree in the General Grant Grove, Kings Canyon National Park) is reported to be 310 feet high (23). Trees with an average basal diameter of 20 feet and a height of 275 feet are common in the southern groves where the best stands are found (21, 28).

Giant sequoias are long-lived (28). Trees in many groves range from 2,000 to 3,000 years old, and a few are over 3,000 years (23, 28). The maximum age has been reported to be over 4,000 years (28), but no authentic records are available to substantiate this claim. The actual age of the oldest living tree is a subject of much speculation and only crude estimates can be made. Ring counts on felled trees indicate ages up to 3,200 years (23). Huge old trees, which were too big to cut in early years and which are now protected, may be much older.

Giant sequoias grow rapidly during their youth; in old age growth is rather slow. Trees under 75 years of age increase in diameter at an average rate of 1 inch every 3 to 5 years, but ancient overmature trees may require more than 20 years to grow 1 inch in diameter (9).

Giant sequoias less than 100 years old retain most of their branches. In contrast, trunks of mature trees are generally free of branches to a height of 100 to 150 feet.

Most giant sequoia groves are on public lands withdrawn from cutting; only 12 percent of the total acreage is in private ownership (6). Very few trees are being cut. In 1952, the latest year of record, about 2,000,000 board-feet were harvested (7). One of the main reasons for the small volume cut is the strong public desire to preserve old-growth trees. Since most "specimen" or "museum" trees are in virgin stands of which 92 percent are publicly owned, the amount cut in the future will probably continue to be small (6)

Although giant sequoias are prized chiefly for their esthetic value, some of the stands could be placed under management for their timber products. In the northern part of the range, there are too few trees to be of economic importance. But in the southern part the trees are more numerous and the areas are better adapted to silvicultural treatments.

Mixed forests in which giant sequoia is an important component could be managed to increase the quality and quantity of this species. About 34 percent of the area growing giant sequoias has been cut-over and is in need of silvicultural treatment. Some cut-overs are poorly-stocked or non-stocked and should be brought up to acceptable stocking standards by planting or special site preparation measures to encourage natural regeneration. Other areas contain overdense thickets which should be thinned to prevent further stagnation and to increase the growth rate of crop trees. And still other areas require stand-improvement measures to release potential crop trees from competition and increase the proportion of giant sequoias in the final stand. In the young stands dominant large saplings and small poles will require pruning to produce clear lumber in rotations of less than 150 years.

Periodic annual growth rates of giant sequoia have not been determined. However, rotation ages for second-growth stands will probably be based mainly on the size of tree that can be harvested without serious loss due to breakage, which runs 45 to 50 percent in old trees. In general, breakage is not a serious factor in young trees.

Reaction to Competition

The capacity of giant sequoia to develop and grow in close competition with other trees is still open to considerable debate. In the revised tolerance table, 25 percent of those receiving the questionnaire rated giant sequoia as tolerant, 50 percent as intermediate, and 25 percent as intolerant (3). Much depends on the period in the life span during which the trees were rated as to tolerance. For best development, giant sequoias require full overhead light (26, 28).

The trees are able to endure more shade during youth than in old age (11, 28). In dense thickets growth is very poor and when released the spindling trees recover slowly; however, after the crown has filled out, growth is rapid. During the first few years, adequate soil moisture is more critical than light for seedling establishment. Young reproduction is generally found only in openings where root competition for moisture has been reduced (17, 18). Small openings are preferable to large ones, mainly because of the lower evaporation rate of soil moisture

and the partial shade in the smaller more protected areas. However, good reproduction has filled in some large areas when logging was followed by a good seed year and favorable climatic conditions.

Principal Enemies

Giant sequoia has few important natural enemies other than fire (12, 28). Ground fires are especially destructive during the seedling and sapling stages (23, 28). Mature trees, protected by an asbestos-like bark up to 2 feet thick, are able to survive repeated fires without serious loss (23). However, after the bark has been burned off, repeated hot fires may hollow-out large trees. Few of the veterans have been destroyed by fire alone, but some have been windthrown where roots were destroyed by fire, road construction or were exposed by erosion following fires. Most of the trees larger than 10 feet in diameter have fire scars (9). Soil compaction by the thousands of tourists that visit the groves each year has seriously reduced the vigor of many large trees (16). Trampling around the base of these trees has destroyed the many feeder-roots necessary to supply the vast quantities of water required by the trees, reduced the water-holding capacity of the soil, and lowered the amount of water penetration into the soil around the trees.

Once established, giant sequoia is noted for its resistance to insect and disease attacks (9, 23, 28). None of the insects reported on giant sequoia has caused the death of a single tree (15). An unidentified brown heartrot has caused some decay in large trees where heartwood has been exposed but no trees have been killed by this disease (28). Old trees which fell centuries ago show very little evidence of decay in the heartwood (23). The 2- to 3-inch layer of sapwood rots away in a few years.

## SPECIAL FEATURES

A high content of tannin in the wood, bark, and cones of giant sequoia protects the tree from seed formation to maturity against attacks by insects or diseases.

The cones contain a highly-colored water-soluble pigment (73 percent tannin, 3 percent organic matter, 1.5 percent ash, and 22 percent water) which has been reported (10) to:

Protect the cones from fungus
Increase the germinative capacity of the seed
Increase the retention of viability of the seeds
Increase the vigor of seedlings
Reduce the susceptibility of seedlings to insect and disease attacks.

## RACES AND HYBRIDS

There are no known races or hybrids of giant sequoia. Two horticultural clons--blue giant sequoia (Sequoia glauca) and columnar giant sequoia (Sequoia pendula)--are listed in Standardized Plant Names (2).

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